Provincial Report

Physics 30
Grade 12 Diploma Examination

April 1984

Student Evaluation

Alberta
EDUCATION

Distribution: Officials of Alberta Education
School Principals
Superintendents of Schools
The Alberta Teachers' Association
Alberta School Trustees' Association
General Public Upon Request

TABLE OF CONTENTS

	PAGE
PREFACE	iii
ACKNOWLEDGMENTS	iv
CHAPTER 1: GRADE 12 DIPLOMA EXAMINATIONS PROGRAM	1
Introduction	1
General High School Diploma	1
Advanced High School Diploma	1
Awarding of Course Credits	1
Transitional Provisions	2
Award of Excellence	2
CHAPTER 2: DESCRIPTION OF THE EXAMINATION	3
Examination Development	3
Examination Description	4
Explanation of Blueprint Thought Levels	6
Description of Subject Matter Areas and Sample Multiple-Choice Questions	7
1. Nature and Behavior of Light	7
2. Electric and Magnetic Fields	8
3. Electromagnetic Radiation	9
4. Structure of Matter	10
5. Modern Physical Theories	11
6. Scientific Process Skills	11
Written-Response Questions	12
CHAPTER 3: RESULTS	17
Validity and Reliability	17
Provincial Averages	17
Comparison of Multiple-Choice and Written-Response Questions	19
Standard-Setting	20
Transformation of Examination Marks	21
Relationship Between Examination Mark and School Mark	22
Results for Individual Questions	23
Multiple-Choice Questions	23
Written-Response Questions	24

LIST OF TABLES

TABLE		PAGE
1	January 1984 Physics 30 Diploma Examination Blueprint	5
2	Provincial Averages for Subtests	18
3	Transformation of Examination Marks	21
4	Summary Statistics for School Mark, Examination Mark, and Final Mark	22
5	Percentages of Students Receiving A's, B's, C's, and F's	22
6	Results for Individual Multiple-Choice Questions	23
7	Distribution of Marks for Written-Response Questions	24
8	Average Marks Awarded for Written-Response Questions	24

PREFACE

This report presents the provincial results of the Physics 30 Diploma Examination administered on January 31, 1984. During this first administration, the Physics 30 Diploma Examination was written by 2684 students. This report is intended to provide more information about the examination development process, the examination itself, and the examination results.

84- 3785 /

ACKNOWLEDGMENTS

This first administration of the Physics 30 Diploma Examination was successful due to the concerted efforts of all involved. Success would have been impossible without substantial contributions from many people, particularly the administrators, teachers, and students, who extended their full co-operation.

The technical expertise and advice received from the Examination Review Committee regarding design, development, and reporting have been particularly valuable in the implementation of this diploma examination. This Committee has representation from:

The Alberta Teachers' Association
The Conference of Alberta School Superintendents
The Universities Co-ordinating Council
The Public Colleges of Alberta
Alberta Education

The contribution of this group is gratefully acknowledged.

Lloyd E. Symyrozum
Director
Student Evaluation Branch

CHAPTER 1

Grade 12 Diploma Examinations Program

Introduction

All Grade 12 students in Alberta are now required to write at least ONE diploma examination to receive a high school diploma. Mature students may receive credits for a Grade 12 course by writing the appropriate diploma examination. They are not required to be registered in the course. The Grade 12 Diploma Examinations Program, which is an integral part of the high school diploma requirements, is intended to develop and maintain excellence in educational standards through certification of academic achievement.

The Diploma Examinations Program consists of course-specific examinations that are based on the prescribed *Program of Studies for Senior High Schools* for the following Grade 12 courses: English 30, English 33, Social Studies 30, Mathematics 30, Biology 30, Chemistry 30, and Physics 30.

Alberta Education issues two distinct high school diplomas: the General High School Diploma and the Advanced High School Diploma.

General High School Diploma

To earn a General High School Diploma, a student must obtain course credit in either English 30 or English 33, and obtain 100 credits distributed over courses as specified in the *Junior-Senior High School Handbook*. Some students who are working toward the general diploma may wish to obtain credits in other diploma examination courses (i.e., Social Studies 30, Mathematics 30, Biology 30, Chemistry 30, and Physics 30). To obtain credits in these courses, a student must also write the appropriate diploma examination regardless of the type of diploma he wishes to receive.

Advanced High School Diploma

The Advanced High School Diploma represents achievement in an academic program that includes language arts (English), social studies, mathematics, and science. To earn an Advanced High School Diploma, a student must satisfy the current course and credit requirements for a General High School Diploma, and obtain course credits in English 30, Social Studies 30, Mathematics 30, and ONE of Biology 30, Chemistry 30, or Physics 30.

Awarding of Course Credits

Grade 10 and Grade 11 Courses. To obtain credits in Grade 10 (10-level) and Grade 11 (20-level) courses, a student must earn a final mark of 40% or better. A student who has achieved a mark of 50% or higher in a given course is eligible to take the next or higher-rank high school course in that sequence.

Grade 12 Courses. To obtain credit in a Grade 12 (30-level) course, a student must earn a final mark of 50% or better. To obtain credit in a Grade 12 diploma examination course, a student must write the appropriate diploma examination and attain a final blended mark of 50% or better. The final blended mark is made up of 50% of the mark awarded by the school and 50% of the diploma examination mark. For example, a student taking Chemistry 30 might have a mark of 45% from his school and a mark of 57% on the diploma examination. This student would earn credits for Chemistry 30 because his final mark would be 51%, which is the average of the school and examination marks. For mature students who do not have a school mark or who have a school mark lower than the examination mark, the examination mark is the final mark.

Transitional Provisions

During the 1983-84 school year, Alberta Education will recognize all course credits earned prior to September 1, 1983, for the purpose of awarding the General High School Diploma.

Students who have completed partial requirements for the Advanced High School Diploma prior to September 1, 1983, and who are enrolled in Grade 12 courses during the 1983-84 school year, may apply any of the previously completed required diploma examination subjects toward a diploma, provided they have earned a final course mark of 50% or better in each subject.

Award of Excellence

When candidates for an Advanced High School Diploma obtain a final average of 80% or higher on the four required diploma examination courses with not less than 65% in any one of these four required courses, they receive an Award of Excellence. This Award of Excellence is noted on the student's Advanced High School Diploma. When a student writes two or three of the diploma examinations in Biology 30, Chemistry 30, and Physics 30, the highest of these final course marks is used for diploma purposes and in the calculation of the average for the Award of Excellence.

CHAPTER 2

Description of the Examination

This chapter outlines the procedures that were followed during examination development and describes the structure and content of the examination. Sample questions from the January 1984 examination are included.

Examination Development

There were three stages in the development of the January 1984 Physics 30 Diploma Examination: preparation of curriculum specifications, development of questions, and selection of questions for the final copy.

1. Curriculum Specifications

   The Curriculum Branch of Alberta Education prepared curriculum specifications based on the topical outline of the Physics 30 core described in the *Program of Studies for Senior High Schools*. In these specifications, weightings were assigned to each major content area and to specific topics outlined in the *Program of Studies*. These weightings were based on the emphasis that each topic was to receive in the Physics 30 program. The curriculum specifications were distributed to all school jurisdictions in the province.

   Topic statements upon which specific questions were based, along with the sample questions for each topic, are given in this chapter.

2. Development of Questions

   Committees composed of teachers and Student Evaluation Branch personnel constructed questions to reflect the content statements listed in the curriculum specifications. The questions were field-tested, and revisions were made on the basis of teacher recommendations and the field test results.

3. Final Copy

   A test development specialist, assisted by groups of classroom teachers, built the examination from suitable questions. These committees selected questions from various content areas, so that each area received the emphasis recommended in the curriculum specifications. An Examination Review Committee checked the proposed examination for content validity, accuracy, and technical merit, and further changes were made in accordance with their recommendations.

Examination Description

On the Physics 30 Diploma Examination, each content area received the following emphasis:

Content Area	Emphasis in % of the Total Examination Mark
Nature and Behavior of Light	20
Electric and Magnetic Fields	26
Electromagnetic Radiation	20
Structure of Matter	20
Modern Physical Theories	14

To the extent that paper-and-pencil testing permitted, the Physics 30 Diploma Examination assessed the application of the scientific process skills of inferring, predicting, hypothesizing, interpreting data, controlling variables, and processing data. The questions that are readily identified with specific process skills are listed below.

Process Skill	Multiple-Choice Question	Written-Response Question
Inferring	1, 16, 34	2
Predicting	3, 5	
Hypothesizing	47	
Interpreting Data	8, 32	
Controlling Variables	6, 18	1
Processing Data		1

Understandably, the experiences gained by direct, hands-on activities are difficult to measure outside a laboratory situation and should therefore be reflected in student performance as evaluated by the teacher.

Subject matter in the attitudinal and psychomotor components of the program was also excluded from the diploma examination.

The time allotted for the Physics 30 Diploma Examination was two and one-half hours. The examination consisted of both multiple-choice questions (worth 80% of the total examination mark) and written-response questions (worth 20% of the total examination mark). There were 55 multiple-choice questions worth one mark each and three written-response questions worth a total of 15 marks.

The classification of examination questions according to content area and taxonomic level is presented in Table 1.

Table 1

January 1984 Physics 30 Diploma Examination Blueprint

Subject Matter Area	Question by Taxonomic Level			Examination Emphasis
	Knowledge	Application and Understanding	Higher Mental Activities	
Light	4,7,10,11	1,2,3,6,9 [1]	5,8	20%
Electric and Magnetic Fields	14,15,20,21, 22,24,25	12,13,16,17,18, 19,23	[3]	26%
EM Radiation	26,30,31,36	27,28,29,34,35 [1]	32,33	20%
Structure of Matter	41,43,44,45	37,38,39,40,42 [1,2]	46,47	20%
Modern Physical Theories	50,53,54,55	48,49,51,52	[3]	14%
Examination Emphasis	35%	50%	15%	100%

Note: Numbers in brackets [ ] indicate the written-response questions. Some written-response questions cover more than one topic.

Explanation of Blueprint Thought Levels

1. Knowledge

   Knowledge is defined as including those behaviors and examination situations that emphasize the remembering, either by recognition or recall, of ideas, material, or phenomena. Incorporated at this level is knowledge of terminology, specific facts (dates, events, persons, etc.), conventions, classifications and categories, methods of inquiry, principles and generalizations, and theories and structures.

2. Application and Understanding

   Application requires the student to apply an appropriate abstraction (theory, principle, idea, method) to a new situation.

   Understanding refers to responses that represent a comprehension of the literal message contained in a communication. This means that the student is able to translate, interpret, or extrapolate. Translation refers to the ability to put a communication into another language. Interpretation involves the reordering of ideas (inferences, generalizations, or summaries). Extrapolation includes estimating or predicting based on an understanding of trends or tendencies.

3. Higher Mental Activities

   Included in higher mental activities are the processes of analysis, synthesis, and evaluation. Analysis involves the ability to recognize unstated assumptions, to distinguish facts from hypotheses, to distinguish a conclusion from statements that support it, to recognize which facts or assumptions are essential to a main thesis or to the argument in support of that thesis, to distinguish cause-effect relationships from other sequential relationships, and to recognize the point of view of a writer.

   Synthesis involves the production of a unique communication, the ability to propose ways of testing a hypothesis, the ability to design an experiment, the ability to formulate and modify a hypothesis, and the ability to make generalizations.

   Evaluation is defined as the making of judgments about the value of ideas, solutions, and methods. It involves the use of criteria as well as standards for appraising the extent to which details are accurate, effective, economical, or satisfying. Evaluation involves the ability to apply given criteria to judgments of work done, to indicate logical fallacies in arguments, and to compare major theories and generalizations.

The taxonomic classification of examination questions may depend on the manner in which the content has been covered in the classroom. A question that is an application question for one class may be a knowledge question for another class.

Questions requiring knowledge and skill in the processes of science were included throughout the examination and are not associated with any specific topic or thought level.

Description of Subject Matter Areas and Sample Multiple-Choice Questions

The topics that were tested within each subject matter area are listed and sample questions from the test are provided. The correct response for each question is identified by an asterisk and the percentage of students selecting each response is given.

1. Nature and Behavior of Light

Questions in this content area are related to reflection and refraction interference, and to propagation, diffraction, dispersion, polarization, and models of light. The specific topic statements covered by the examination were:

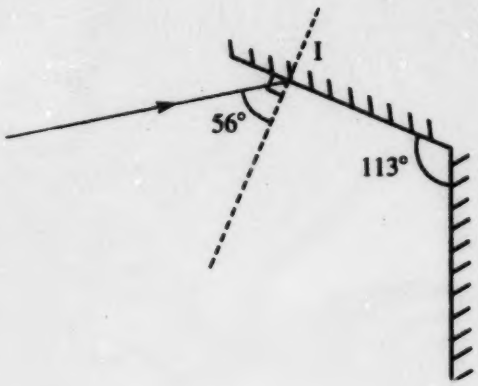
- light travels in straight lines
- Olaf Römer gathered data to measure the speed of light
- the angle of reflection is equal to the angle of incidence
- refraction involves a change of wavelength and speed as a wave goes from one medium to another
- when a light ray is split into beams, interference results if two beams are allowed to overlap
- white light is a mixture of all colors
- since light can be polarized, it is propagated by transverse waves
- the wave model requires that light travel through an ether

The following example requires students to make a prediction based on an understanding of principles related to the reflection of light from plane surfaces. To make the prediction, students must analyse the information provided in the diagram. This process is considered a higher mental activity.

Question 5:

Use the following information to answer question 5.

In the diagram to the right a ray of light hits the first mirror at point I and is reflected to the second mirror, where it is reflected again.



If the angle of incidence is 56° and the angle between the mirrors is 113°, then the angle between the final reflected ray and the second mirror is

Student Responses

22.9%	A.	57°
15.9%	B.	34°
45.7%	*C.	33°
15.4%	D.	11°
0.1%		no response

2. Electric and Magnetic Fields

Questions in this content area are related to the nature of electric charges and forces, forces and fields, moving charges, and moving charges and magnets. The specific topic statements covered by the examination were:

- Gilbert does not accept the Effluvium Theory
- electric charges and electric forces
- the unit of charge
- fields
- electric potential difference, current, and power
- a magnetic field without a magnet
- currents act on currents
- magnetic fields and moving charges

The following example requires students to apply knowledge related to the interaction of moving charged particles with electric and magnetic fields. Students must decide which variables are necessary to the solution of the problem and relate these variables to one another.

Question 18:

Charged particles with varying speeds enter a region having an electric field E and magnetic field B = 5.0 T. When $\vec{v}$, $\vec{B}$ and $\vec{E}$ are perpendicular to each other, the electric field required to permit the undeflected passage of only the particles with speed 2.0×10^5 m/s is

Student Responses

25.1%	A.	1.6×10^{-13} N/C
9.5%	B.	2.5×10^{-5} N/C
9.0%	C.	4.0×10^{4} N/C
56.0%	*D.	1.0×10^{6} N/C
0.4%		no response

3. Electromagnetic Radiation

Questions in this content area are related to electromagnetic theory, the propagation of electromagnetic waves, evidence for the electromagnetic spectrum, and a description of the electromagnetic spectrum. The specific topic statements covered by the examination were:

- Maxwell's mathematical model of magnetic induction
- speed and propagation of waves depends upon stiffness and density of the medium
- Hertz investigated evidence of electromagnetic waves at various frequencies
- energy and moving charges together produce radiation away from a source as an electromagnetic wave

The following example requires students to recognize the characteristics of a specific region of the electromagnetic spectrum. Students must be able to distinguish wave-like behavior from particle-like behavior for each of the regions of the spectrum.

Question 31:

The wave nature of X-rays is demonstrated by their ability to

Student Responses

53.7%	*A.	be diffracted by crystalline solids
35.8%	B.	penetrate many solids
6.0%	C.	ionize air molecules
4.5%	D.	be produced by Crookes' tube

4. Structure of Matter

Questions in this content area are related to the chemical and electrical nature of the atom, the quantum behavior of matter, and the Rutherford and Bohr models of the atom. The specific topic statements covered by the examination were:

- Dalton's interpretation of experimental facts made possible some conclusions concerning the nature of atoms
- Michael Faraday discovered two fundamental laws of electrolysis
- J. J. Thomson conducted a series of experiments that indicated that cathode rays are negatively charged particles
- Robert Millikan measured the charge of the electron
- Einstein explained the photoelectric effect
- Bohr introduced three postulates designed to account for the existence of stable electron orbits and discrete emission spectra
- the Bohr model could be used to explain all emission and absorption lines in the hydrogen spectrum
- discrepancies exist between theory and experiment

The following example requires students to apply knowledge related to the Bohr model of the atom. Students must determine the initial and final energy states of the electron, determine the energy difference and translate this energy difference into a corresponding wavelength for the light that is emitted.

Question 42:

Use the following information to answer question 42.

Energies of some of the stationary states of hydrogen

$n = \infty$	0.0 eV
•	•
•	•
•	•
$n = 4$	-0.8 eV
$n = 3$	-1.5 eV
$n = 2$	-3.4 eV
$n = 1$	-13.6 eV

An electron makes a transition from $n = 4$ to $n = 2$. The wavelength of the corresponding spectral line is

Student Responses

7.9%	A.	7.7×10^{-7} m
11.8%	B.	6.7×10^{-7} m
8.9%	C.	5.7×10^{-7} m
70.9%	*D.	4.8×10^{-7} m
0.4%		no response

5. Modern Physical Theories

Questions in this content area are related to the results of relativity theory, the particle-like behavior of radiation, the wave-like behavior of particles, the Schrödinger equation, Heisenberg's uncertainty principle, and quantum mechanics. The specific topic statements covered by the examination were:

- the relationship of relativistic mass and rest mass
- if a quantum has energy, then it also has momentum
- the Compton effect was a successful demonstration of the momentum of a quantum
- some wave properties of the electron can be measured
- the more accurately the electron is located, the less accurately we know its velocity
- Schrödinger's wave equation gives us the probability for finding particles

The following example requires students to apply knowledge related to relativity theory. Students must be able to rearrange the relativistic mass equation to solve for the velocity of a moving particle.

Question 51:

If a proton's relativistic mass is 2.1×10^{-27} kg, its speed is

Student Responses

21.6%	A.	1.9×10^{8} m/s
47.5%	*B.	1.8×10^{8} m/s
20.3%	C.	1.3×10^{8} m/s
10.4%	D.	1.1×10^{8} m/s
0.3%		no response

6. Scientific Process Skills

The process skills covered by the examination were:

Inferring - the process of arriving at a tentative explanation or conclusion based on direct or indirect observations.

Predicting - the process of formulating a specific forecast of what a future observation will be. Predicting often involves interpolating and extrapolating.

Hypothesizing - the process of proposing a tentative explanation, based on observations or inferences, for the occurrence of a set of observations or events. Hypotheses must be testable in order to be valid.

Interpreting data - the process of recognizing patterns in data, identifying relationships between variables, and forming generalizations.

Controlling Variables - the process of deciding which variables or factors will influence the outcome of an experiment, situation, or event. In an experimental situation, the variables of interest are free to vary in response to variables over which the experimenter exercises control. Controlled variables are allowed to take on specific values.

Processing Data - the process of organizing rough data in a more compact and meaningful way (through ordering, rearranging, comparing), depicting the data pictorially or graphically, and processing data mathematically (finding slopes, tangents, etc.) to facilitate interpretations.

The following example of hypothesizing requires students to recall observations and events associated with quantum theory and select proposed tentative explanations which, if tested, would prove to be valid.

Question 47:

Use the following information to answer question 47.

> Two hypotheses relating to an atomic model in which electrons orbit a nucleus are:
>
> I Electrons lose energy and fall into the nucleus.
> II Electrons emit radiation continually.

According to quantum theory, which of the following should occur?

Student Responses

43.9%	*A.	Neither I nor II
13.4%	B	Both I and II
14.9%	C.	Only I
27.7%	D.	Only II
0.0%		no response

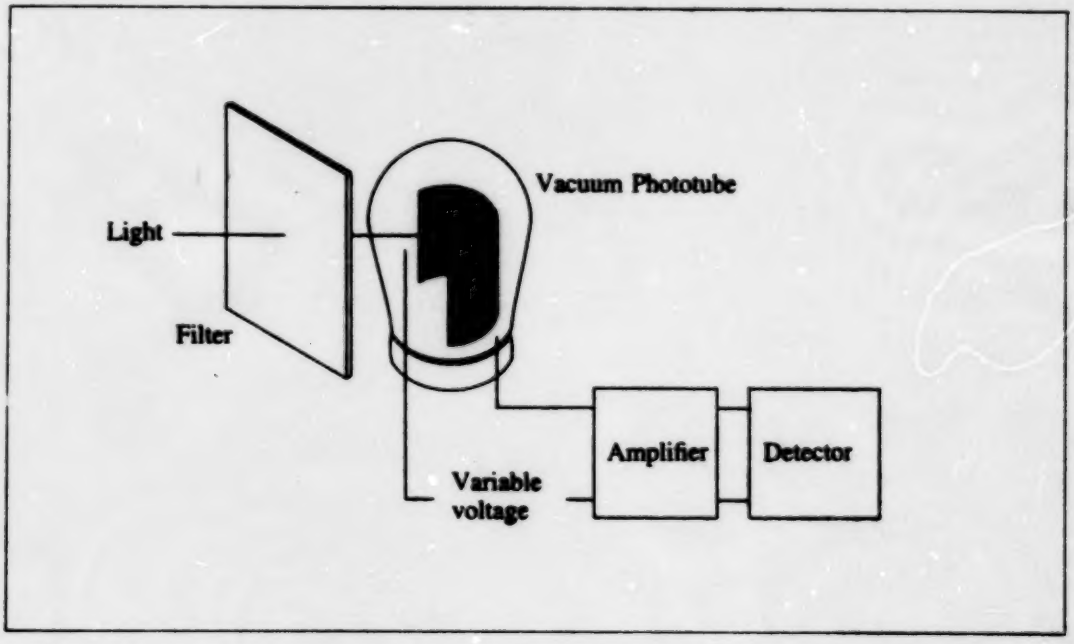
Written-Response Questions

In this section, students were expected to communicate their answers clearly and identify steps in their solutions. All answers were to give the correct number of significant figures in calculations and include appropriate units.

Each written-response question from the examination is given on the following pages with an appropriate answer. The total marks possible for each question is given, along with the average number of marks awarded. The distribution of marks awarded to students for each written-response question is shown in Table 7, Chapter 3.

Question 1 reflects a strong process emphasis incorporated into an item that requires students to integrate the concept of photoelectric effect and the relationship between the frequency of absorbed light and the maximum kinetic energy of photoelectrons.

Two student groups used a photoelectric cell and color filters to determine the stopping voltage for three colors of light. Sunlight was allowed to fall directly on the cell and the voltage required just to stop the flow of electrons was determined. Each of the three color filters was then placed in succession over the cell, and stopping voltages were determined. A diagram of the apparatus used and the results recorded by each group are given below.



RESULTS

Filter	Freq. Transmitted ($\times 10^{14}$ Hz)	Stopping Voltages (V)	
		Group I	Group II
1	ALL	1.88	1.73
2	8.2	1.45	1.35
3	6.8	0.91	0.74
4	6.0	0.42	0.38

a. The DEPENDENT variable in this experiment is

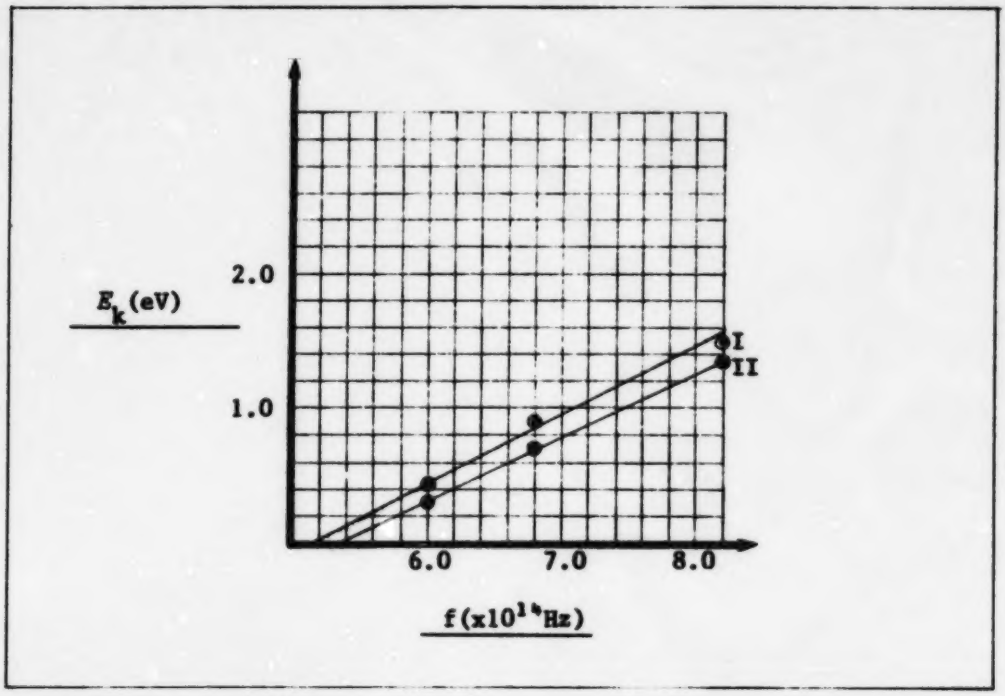
Key: stopping voltage

b. The INDEPENDENT variable in this experiment is

Key: frequency of light

c. On the graph provided, plot the frequency transmitted and the maximum E_k of emitted photoelectrons. Be sure to label both axes. NOTE: Plot the data for Groups I and II separately.

Key:



d. From the graph of Group II's data, determine the value of Planck's constant, h. Show ALL your calculations.

Key:

$$h = \text{slope} = \frac{\Delta E_{k_{max}}}{\Delta f} = \frac{(1.35 - 0.38)\ \text{eV} \times 1.60 \times 10^{-19}\ \text{J/eV}}{(8.2 - 6.0) \times 10^{14}\ \text{Hz}}$$

$$h = 7.0 \times 10^{-34}\ \text{J}\cdot\text{s}$$

e. What is the percentage error between the value obtained in "d" and the actual value of Planck's constant? NOTE: If you were unable to determine a value for Planck's constant, use $h = 7.0 \times 10^{-34}$ J·s for your calculation here.

Key:

$$\%\ \text{error} = \frac{(7.0 \times 10^{-34} - 6.63 \times 10^{-34})\ \text{J}\cdot\text{s}}{6.63 \times 10^{-34}\ \text{J}\cdot\text{s}} \times 100$$

$$\%\ \text{error} = 5.6\ \%$$

It was possible to score 8 marks for this question. The average number of marks awarded to students was 2.6.

Question 2 requires students to make an inference regarding the mass of a single item based on given results of an experiment. The remainder of this question asks students to identify the famous analogous experiment and the result of the experiment.

The following experiment was performed by a group of students.

The masses of several boxes containing identical items were determined. The boxes each had exactly the same mass. The number of items in any box was unknown.

The results of the experiment are given below.

Box Number	Mass of Box and Contents (g)
1	5.51
2	4.51
3	4.01
4	3.41
5	3.31
6	2.71
7	5.61
8	3.11
9	4.91
10	3.21

a. Without knowing the box mass or the number of items in any box, what may be inferred concerning the mass of a single item?

Key: The mass of a single item may be inferred to be 0.10 g.

b. Name the historic experiment to which this experiment is related.

Key: Millikan's oil drop experiment

c. State the result of the historic experiment.

Key: It provided the basis for the determination of the smallest unit of charge.

It was possible to score 3 marks for this question. The average number of marks awarded to students was 0.73.

Question 3 requires students to synthesize principles related to modern physical theories and electric and magnetic fields.

An alpha particle travelling at a relativistic speed of 1.5×10^8 m/s enters a uniform magnetic field at an angle of 90.0° to the field. If the field has a flux density of 0.80 T, what is the radius of curvature for the path of the alpha particle? Give a written explanation for any formulas that you use. Show ALL your calculations and express your answers to the appropriate number of significant figures.

Key: The relativistic mass of the alpha particle must be determined.

$$m = \frac{m_0}{\sqrt{1 - v^2/c^2}}$$

$$m = \frac{6.65 \times 10^{-27} \text{ kg}}{\sqrt{1 - (1.5 \times 10^8 \text{ m/s})^2/(3.0 \times 10^8 \text{ m/s})^2}}$$

$$m = 7.7 \times 10^{-27} \text{ kg}$$

An alpha particle travelling perpendicularly to a uniform magnetic field moves in a circular path. Hence the magnetic force on the proton results in centripetal acceleration. Therefore,

$$F_c = F_m$$

$$\frac{mv^2}{R} = qvB_\perp$$

$$R = \frac{mv}{qB_\perp}$$

$$R = \frac{(7.7 \times 10^{-27} \text{ kg})(1.5 \times 10^8 \text{ m/s})}{(2 \times 1.60 \times 10^{-19} \text{ C})(0.80 \text{ T})}$$

$R = 4.5$ m This answer must be expressed to the correct number of significant figures. The units for the answer in this case must be metres.

It was possible to score 4 marks for this question. The average number of marks awarded to students was 1.1.

CHAPTER 3

Results

Validity and Reliability

The content validity of the examination was established by the procedure for examination development outlined in Chapter 2. Each question was mapped to a specific topic statement defining some aspect of the curriculum. The Examination Review Committee evaluated each question, and the examination as a whole, for content validity.

The KR-20 coefficient for the multiple-choice portion of the examination was 0.85, and Cronbach's alpha for the total test was 0.86. These values are very satisfactory for an achievement test measuring a broad range of concepts and skills.

The inter-marker reliability for the marking of the written-response questions was also examined. The marking key for each question was prepared by the Student Evaluation Branch and then revised following discussion with four head markers. During the orientation session, teachers marked three common student responses for each question and discussed the awarding of marks. All teachers then marked an additional three student responses for each question so that the consistency of the marking procedures could be checked. At the beginning of each morning and afternoon marking session, all teachers marked two common student responses for each question. Any discrepancies were again discussed. For questions on those papers marked by all teachers, 78.1% of the marks awarded were in agreement, 19.3% deviated from the consensus mark by one mark, and 2.6% deviated by more than one mark. During the marking, one teacher marked question 1, and a different teacher marked questions 2 and 3 for each paper.

Provincial Averages

The classification of examination questions according to subject matter topic and taxonomic level has been presented in Table 1, Chapter 2. Subtest scores were computed for each of the five subject matter topics, for the three taxonomic levels, and for the questions requiring the application of scientific process skills. Table 2 contains the provincial averages for these subtests and for the total examination. In each case, an average is given for the written-response questions, the multiple-choice questions, and the combination of the two (total). Averages are based on raw scores, which are the number of marks obtained on each subtest. The total marks possible is identified for the written-response and multiple-choice components of each subtest. For the multiple-choice component of each subtest, the average in per cent is also given.

Averages are based on 2684 students. Differences between total averages and component averages are due to rounding.

Table 2

Provincial Averages for Subtests

Subtest	Total Marks Possible		Raw Score Averages		
	Written-Response	Multiple-Choice	Written-Response	Multiple-Choice	Total
Topics					
Nature and Behavior of Light	0	11	--	7.1 (64.5%)	7.1
Electric and Magnetic Fields	0	14	--	8.9 (63.6%)	8.9
Electromagnetic Radiation	8	11	2.6	7.1 (64.5%)	9.7
Structure of Matter	3	11	0.7	6.6 (60.0%)	7.3
Modern Physical Theories	4	8	1.1	4.7 (58.8%)	5.8
Process Skills	11	10	3.4	5.7 (57.0%)	9.0
Taxonomic Levels					
Knowledge	0	23	--	13.9 (60.4%)	13.9
Application and Understanding	11	26	3.4	17.4 (66.9%)	20.7
Higher Mental Activities	4	6	1.1	3.1 (51.7%)	4.2
TOTAL EXAMINATION	15	55	4.4	34.4 (62.5%)	38.8

The standard deviation for the total examination was 11.2 raw score points.

Total marks possible in Table 2 differ from those given in Table 1 because written-response questions that cover more than one subject matter area have been allocated to only one subtest for reporting purposes.

The multiple-choice averages in per cent provide an indication of how well students performed within subject matter topics and taxonomic levels. There are no large differences in the averages for the five topics. The average for the six multiple-choice questions involving higher mental activities was considerably below the average for the multiple-choice portion of the test. The difficulty of these questions probably results from the complexity of the information that the students must manipulate in order to answer them.

It is not meaningful to compare total subtest scores or written-response subtest scores across topics or taxonomic levels because of the uneven distribution of written-response questions. However, jurisdictions and schools can compare their averages to the provincial averages to help identify strengths and weaknesses in their programs.

Comparison of Multiple-Choice and Written-Response Questions

The average mark attained on all multiple-choice questions was 62.5%, and the average on all written-response questions was 29.3%. It is not readily apparent why the written-response question were answered so poorly.

In this section, each written-response question is discussed in relation to comparable multiple-choice questions.

In written-response question 1, the average number of marks awarded was 2.6 out of a possible 8 marks. This question required students to understand that kinetic energy can be calculated from the stopping voltage, and that Planck's constant can be derived from the slope of the graph.

Question 1 can be compared with multiple-choice question 37, as they are similar with respect to type and complexity of calculations required.

Comparable Questions	Difficulty Levels
written-response 1	0.33
multiple-choice 37	0.66

The difference in performance and related difficulty of the written-response question may be due to the fact that six of the eight marks awarded are directly related to successful performance of process skills. In parts a and b, students were required to identify the independent and dependent variables within the context of the experiment described. In part c, students were required to process the data by graphing. They were required to assign the independent and dependent variables to the *x* and *y* axes respectively, include unit definitions with axes labels, and plot the data. In part e, students were required to interpret the accuracy of the experimental result by calculating per cent error.

In written-response question 2, the average number of marks awarded was 0.7 out of a possible 3 marks. Both written-response question 2 and multiple-choice question 46 refer to Millikan's oil drop experiment.

Comparable Questions	Difficulty Levels
written-response 2	0.24
multiple-choice 46	0.35

The greater difficulty of written-response question 2 may be due to the extra component that requires the student to draw an inference from the situation described.

Students did not appear to be prepared for the inclusion of these process components.

Multiple-choice questions 18, 23, and 51 require the student to make the same calculations required in written-response question 3.

It is difficult to compare written-response question 3 with any single multiple-choice question because of its "synthesis" and two-stage nature, which increase its difficulty. However, it would appear from the following difficulty levels that students can handle each step separately, but have trouble combining these procedures.

Comparable Questions	Difficulty Levels
written-response 3	0.28
multiple-choice 18	0.56
multiple-choice 23	0.59
multiple-choice 51	0.48

Students seemed to have problems similar to those they experienced with the other two written-response questions.

Standard-Setting

Every effort was made to design a Physics 30 diploma examination that would be a valid and reliable measure of what students can be expected to know as a result of instruction in this course. A specific standard or level of expectation inherent in the examination was established through careful test development procedures. To ensure that each form of the examination administered in 1984 will be parallel to each other, the Student Evaluation Branch has adopted a process of standard-setting. One way to review the standards inherent in each examination is to involve classroom teachers in making judgments about the difficulty of the examinatior.

The teachers who marked the written-response portion of the examination reviewed the difficulty level of each question in terms of a borderline passing student (who merits 50%), a borderline "B" student (who merits 65%), and a borderline "A" student (who merits 80%). After teachers gave their initial judgments on question difficulty, they were given information about the actual distribution of students' examination marks. They were then given the opportunity to modify their judgments. Judgments from all teachers for all examination questions were pooled to determine the examination scores that teachers felt should be set equivalent to 50%, 65%, and 80%. For the January 1984 diploma examination, teachers felt that 39% should be raised to 50%, that 56% should be raised to 65%, and that 76% should be raised to 80%. These cut-off scores are based on the judgments of 20 teachers.

Transformation of Examination Marks

The final decision on the transformation to be applied to the examination scores was based on an analysis of the data from the teachers' judgments, the distribution of examination marks, the distribution of school marks, and the distribution of marks in previous years. The examination marks were adjusted according to the transformation presented in Table 3.

Table 3

Transformation of Examination Marks

Actual Examination Marks (%)	Adjusted Examination Marks (%)
0 - 42	0 - 47
43 - 59	50 - 64
60 - 76	65 - 79
77 - 100	80 - 100

Scores between the two end points of each interval were converted according to linear transformation. Additional adjustments were made to the examination marks so that students would not receive final blended marks of 48% or 49%.

The overall effect of the transformation was to raise the average from 55.4% to 60.3%.

Relationship Between Examination Mark and School Mark

The provincial averages and standard deviations for the school-awarded mark, the transformed examination mark, and the final blended mark are presented in Table 4.

Table 4

Summary Statistics for School Mark, Examination Mark, and Final Mark

	School-Awarded Mark	Examination Mark	Final Blended Mark
Average	67.6%	60.3%	64.3%
Standard Deviation	13.5%	15.3%	13.2%

The average school mark was 7.3% higher than the average examination mark after transformation. The correlation between school mark and examination mark was 0.68, which indicates a fairly close agreement in the rank ordering of the students based on the two sets of marks.

The percentages of students receiving A's, B's, C's, and F's are presented in Table 5 for the school mark, examination mark, and the final blended mark.

Table 5

Percentages of Students Receiving A's, B's, C's, and F's

Score	School-Awarded Mark	Examination Mark	Final Blended Mark
A(80-100%)	22.1	11.9	13.7
B(65-79%)	36.8	27.2	34.7
C(50-64%)	33.6	38.9	41.2
F(0-49%)	7.5	22.0	10.4

Results for Individual Questions

Multiple-Choice Questions

The percentage of students choosing each response for each multiple-choice question (item) is given in Table 6. The correct response (key) for each question is also identified.

Table 6

Results for Individual Multiple-Choice Questions

ITEM	KEY	Distribution of Responses in %*				ITEM	KEY	Distribution of Responses in %*			
		A	B	C	D			A	B	C	D
1	D	10.5	9.2	16.7	63.5	29	A	47.2	17.0	19.7	15.9
2	A	56.9	8.7	14.0	20.3	30	A	65.7	13.3	6.3	14.6
3	C	5.0	12.9	57.3	24.7	31	A	53.7	35.8	6.0	4.5
4	D	6.3	6.6	31.8	55.3	32	C	15.4	9.1	61.7	13.4
5	C	22.9	15.9	45.7	15.4	33	B	11.0	60.5	18.5	9.9
6	C	27.9	12.1	53.4	6.6	34	D	19.4	10.8	18.5	51.2
7	B	8.5	76.0	3.9	11.4	35	B	5.8	87.9	2.8	3.5
8	D	13.6	7.4	12.9	66.1	36	C	12.4	7.2	58.2	22.2
9	B	2.2	87.2	9.2	1.2	37	C	4.8	20.8	65.6	8.6
10	D	3.9	3.2	12.7	80.1	38	D	2.1	7.9	8.9	81.0
11	D	9.1	5.4	12.8	72.7	39	B	3.7	74.2	12.2	9.8
12	C	11.3	8.6	76.0	3.9	40	B	14.1	68.9	11.0	5.4
13	A	90.4	3.2	4.1	2.0	41	C	16.0	11.0	65.6	7.3
14	C	3.7	11.7	70.3	14.3	42	D	7.9	11.8	8.9	70.9
15	A	70.9	7.6	8.4	12.9	43	C	20.1	13.3	34.4	32.2
16	C	7.9	19.0	67.6	5.4	44	B	16.8	63.3	4.0	15.8
17	B	7.4	50.5	24.4	16.7	45	C	11.8	21.9	52.0	14.3
18	D	25.1	9.5	9.0	56.0	46	C	33.8	16.6	35.3	13.6
19	C	14.9	11.4	68.7	4.7	47	A	43.9	13.4	14.9	27.7
20	C	21.9	24.2	39.3	14.5	48	C	6.4	9.4	79.9	3.8
21	B	20.6	49.4	12.4	17.4	49	D	4.1	9.5	36.5	49.8
22	A	69.2	7.9	10.5	12.3	50	C	12.9	15.4	58.9	12.9
23	B	4.2	59.1	21.2	14.4	51	B	21.6	47.5	20.3	10.4
24	A	59.9	6.7	6.5	26.6	52	B	7.0	80.8	7.2	4.6
25	A	58.6	11.2	13.0	17.2	53	A	52.6	21.2	12.0	14.0
26	C	5.6	8.0	80.1	6.3	54	B	41.9	41.9	5.5	10.2
27	B	24.9	57.7	8.1	9.2	55	D	7.5	21.1	11.8	58.5
28	D	3.8	3.4	4.1	88.7						

*The sum of the percentages for each question is less than 100% because the No Response category is not included. This category is equal to or less than 1% for all questions.

Written-Response Questions

The percentage of students awarded each mark for each question is given in Table 7.

Table 7

Distribution of Marks for Written-Response Questions

Question	Percentage of Students Obtaining Each Mark									
	NR*	0	1	2	3	4	5	6	7	8
1	3.0	14.0	17.9	18.9	16.7	10.9	7.2	5.6	3.3	2.5
2	13.1	46.6	14.4	18.9	7.0					
3	22.8	23.2	20.8	19.8	4.5	8.9				

*NR - No Response

The total number of marks possible, the average mark awarded to students, and the difficulty level for each written-response question are summarized in Table 8. The difficulty level is the average divided by total marks possible.

Table 8

Average Marks Awarded for Written-Response Questions

Question Number	Total Marks	Average	Difficulty Level
1	8	2.6	0.33
2	3	0.73	0.24
3	4	1.1	0.28

POOR

QUALITY

ORIGINAL